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POLAR LIGHT

Tai Nien-tsu

People in the northeastern, northwestern and northcentral regions of our country at times might see a strange light composition at night in the northern sky. It sometimes resembles the movements of a snake, or of a velvet curtain in a theater or of a fire on a distant mountain, or a herd of sheep scattering around. It may sometimes be imagined as a heavenly eye quietly peeked into this world. We called this beautiful light scenery the north polar light.

In contrary to the north polar light, there is also a south polar light. However, because of the geographic location of our country, we are generally unable to observe it. Regardless of north or south polar light, it is a natural occurring, but how does it happen?

Fig. 2. Chang-keng (evening star)

Fig. 3. Resembling movement of a snake.

Figure 4. A moonlike large star followed by a group of small ones.

THE FORMATION OF POLAR LIGHT

Though ancient people were always able to see the polar light, and never failed to record their observation, they were unable to explain its formation satisfactorily. Generally, its formation is related to the movement of the sun, the magnetic field of the earth and the atmosphere about the earth.

Actually, the sun is not as quiet as it has appeared to us. It is in a constant vigorous activity and it radiates its black spots and glittering sun rays. As the sun, composed of extremely density material at very high temperature, is continuously undergoing vigorous nuclear reaction, it releases a hugh amount of energy. As a result, the sun emits numerous electronic particles into the solar space. When the large amount of electrons and

Fig. 1 Shapes of polar light.

Fig. 5 Tien-gou (proboscis)

Fig. 6 A well-eye in the sky

Fig. 7 Ge-tse (latticed mash)

positrons enter the magnetic environment of the earth, they will change their directions. They move in the atmosphere along the magnetic field of the earth to the poles at a speed of 360-700 metric miles/sec. Meantime, they energize the molecules in the air and cause the formation of light. Because of the difference in atmospheric composition, the color of light observed varies. When the electronic particles enter the atmosphere, they are absorbed by the air. However, at approximately 80 m. miles above the surface of the earth, they are absorbed entirely and the polar light cannot be observed.

In recent years polar lights have also been fabricated. They can be created from an electronic gun mounted on a rocket. The gun shoots highly energized electrons into the electronic and magnetic fields of the sky, which enter the northern or southern hemisphere according to its designated speed and the magnetic field of the earth. It forms a colorful polar light. However this man-made polar light covers only a small area and the duration is quite short.

Intensity, Shape and Color

How bright is the polar light?

Its intensity varies. A weak polar light barely resembles a visible milky way. However a bright one may be as conspicuous as a bright moon. Within a polar light itself, its intensity may be different. It appears the brightest at 5~10 m. miles from its lowest point and decreases sharply from there on. The intensity not only varies from one polar light to another, but also changes constantly within a polar light.

The shape and activity of a polar light is also highly variable. Its shape may resemble a curtain (Figure 1_1), a crown

(Figure 1_2), a collection of dots, a bend, or an arc (Figures $1_{3,}$ $_{4,\ 5,\ 6}$); a bundle or a column (1_7). Its composition may include slices (Figure 1_9); lines (Figures $1_{1,\ 2,\ 5,\ 6,\ 7}$) and dots. Its continuous movement resembles a stream of stars (Figure 1_8). The modern classification of polar lights relies on its shape, composition, and activity. It may be called a calm light arc (Figure 2), and active light bend, at times accompanied by small bends (Figure 3), an active light arc (a part might vary its intensity periodically Figure 4), a light bundle which includes light crowns (Figure 5, 6) and a light ball etc.

The color of the polar light also changes continually. Generally it appears in yellow-green but occasionally it may also be white, red, blue or light purple. These colors vary with the environment of the upper atmosphere. For example, yellow-green and red associate with elemental oxygen, while molecular nitrogen relates to blue and purple colors.

Because of the above characteristics, the polar light often arouses perplexity and stimulates the imagination of the observer.

The Distribution of the Polar Light

The line connecting the places having the same average number of polar lights is called equi-frequency line. Since the earth poles and earth magnetic poles differ by 11° and the magnetic fields of the north and south poles are not identical, the polar light equi-frequency line does not coincide with the latitudes of the earth but forms an imperfect circle around the magnetic poles. From estimations, the lines of maximum frequency are not at the magnetic poles but at about 22~27° from them. The probability of observing the polar light decreases when going away from these maximum frequency circles. In our northern hemisphere, the value

of the maximum polar light frequency is 243 days or two-thirds of a year. This line runs roughly through northern Alaska, northern Canada, southern Iceland, northern shore of Norway, south part of Sunda Island (Saint David's Island?) [Translator is not sure of the name of Island] and the southern part of New Siberia Islands. The isochasm value in northern Heilungkiang Province of China is one, meaning that the chance of seeing the polar light here is only one day in a year. In the eastern part of Inner Mongolia, the northern Kirin, southern part of Heilungkiang, and northern Sinkiang Provinces, the probability is once in every ten years. Of course, this is only statistical and may be changed in the future. In a certain year when the sun in active, the chance to see a polar light will increase. Since the location and the size of magnetic field of the earth is constantly changing, the distribution of the polar light is also changing. ON ~~In~~ September 7, 1956, a polar light was observed in the Altai district of Sinkiang Province. On March 8, 1964, a large pink curved polar light also appeared for six hours above the city of Tsitsihar.

A polar light generally appears in regions of high latitude in either the northern or the southern hemisphere, but in some rare case, it may also appear in low-latitude regions. For example, one was sighted on February 4, 1872 in the Kuang-hua district of Wupei Province. One was even observed in Bombay, India, lasting from 11 pm until dawn, and accompanied by a strong magnetic explosion. Several polar lights have also been observed in tropical areas over a century. Within a given year, polar lights have been observed mostly in mid-Spring or mid-Autumn (or around March and September).

Abundant Historical Record

Nowadays, it is rare occasion to be able to see a polar light in the Peking area. However, workers in ancient Sian, Peking, Loyang, even Hangchow could see it easily. This is because on one hand that there were no distraction from the modern city lights; on the other, the earth's magnetic poles have been changing incessantly from the

historical period. At one time the polar lights have been concentrated over the northern part of our country, unlike the distribution nowadays. Therefore there was more chance to observe the polar light in ancient times.

Writings concerning polar lights were claimed to have been found as early as the Huangti Period, and records showed that there were more than 170 sightings between the first and tenth century. A maximum number of 145 was recorded between the 11th and 12th centuries. One of the earliest and most accurately recorded polar lights, on October 27, 32 B.C., was described in an ancient astronomy document as follows: (in ancient Chinese, paraphased), "A polar light was sighted near Ursa Major on October 27, 32 B.C. It appeared white, very bright, approximately 40 to 60 feet long, curved, and moving like a dragon or snake (Figure 3). Its shape and width may change indefinitely." One may sense the realness of the polar light in this ancient description. In such a short paragraph, it has described a detailed polar light including its time, shape, color, intensity, change of movement and dimensions. The place of observation may have been Changan, the capital of the Western Han Dynasty, now the city of Sian.

According to historical record, a polar light was observed during the Huangti Period. Based on the ancient description, it was circular or curved. One of the most frequently recorded colors of the polar lights was red. Thus, it was commonly known to the ancient working people as "red vapor". The ancient polar light has been described in more than 12 terminologies, as represented in the drawings in Figure 8.

Was the polar light associated with a noise? The scientists are still uncertain and further verification is needed. According to some of our ancient records, a sound was reported to accompany a certain type of polar light, as described in the "Five Primary Elements"

of the Sung Dynasty, which concerns a polar light appearing on May 11, 1119. However, such a case was very rare and there were only several cases out of hundreds of sightings over several thousand years.

Polar light, an Earth-Physics subject, is an important aspect for studying the relationship between the sun and the earth, linked together Earth-Physics, Solar-Physics and Atmospheric-Physics. The rich information in polar light in Chinese literature should be a useful reference for studying historical solar activity, the change of earth's magnetic field, the movement of magnetic polar positions, historical weather change patters and earthquakes.

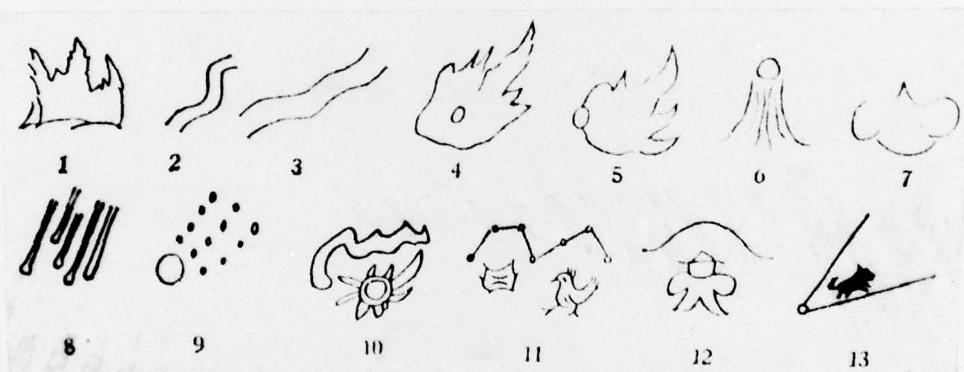

Figure 8. Shapes of polar light drawn in 17th century in China. Key: 1 - Banner of Ch'ih-yu; 2 - Crooked arrow; 3 - Evening star; 4 - Ge-tse (lattice mash); 5 - Han-yu; 6 - Yu-han; 7 - Kuei-hsieh (deviator); 8 - Parallel shooting of stars; 9 - A moon-like large star followed by a group of small ones; 10 - Drizzling star; 11 - Beginning of ten-day cycle; 12 - Tien-ch'ung (soaring to the sky); 13 - Tien-gou (proboscis).

THE ~~MOVEMENT~~ ACTIVITY OF THE SUN AND THE CHANGE OF WEATHER

Chang Sien-Kung

The weather about the earth is changeable. The weather change has been one of the most important problems in meteology and how well we can long term forcast will hinge on how well can we understand this problem. Consquently, it has received wide attentions.

From the beginning of this century, the temperature around the world has generally increased, including our country. The increase topped out in the 1940's, then decrease gradually, most evidently in the summer or autumn. Then the extensive raining season came in the 50's caused the most extensive flood of the century in the Yangtze river territories. However, there were a number of draught years in the 60's. The above instances are examples of weather change. Researching on weather change, we should understand the facts in the past, analyze the reasons for the change and most importantly apply the generalities for the future, to serve our socialist economy and defense.

WHAT IS THE MOVEMENT OF THE SUN

According to the modern knowledge there are many factors affecting the weather but may be summarized as follows: the radiation of the sun, the surface of the earth (land and sea) and air-movement. All three factors are mutually related but the most important one is solar radiation. It can be considered in two aspects: fixed radiation which amounts more than 90% of the energy, including visible, near-infrared and near-ultraviolet rays, and variable radiation which includes electronic waves, ultraviolet waves and particle movement of the electromagnetic radiations. With the advent of atmosphere science and solar physics, it has been discovered that

the activity of the sun can cause 2.5% change in the fixed radiation (mainly in visible rays). Moreover, the ultraviolet portion of the sun rays may at times intensify up to several decades or several hundred folds, especially the change of intensity of the particle movement. The energy accompanied the particle movement to the earth's atmosphere is several magnitude more than the electro-radiation of the variable radiation. The so called solar activity, meaning a series of physical processes resulted from its own disturbance can significantly affect the variable radiation of the sun.

The activity of the sun may be represented by the change in number of its black spots. A complete and reliable record may be traced back to 1749 (Figure 1) and years of periodic extreme values (highest and lowest) to 1610. Recently, the Peking Observatory deduced the solar activity of the past more than ten centuries on the basis of ancient polar lights and black spots information. The black-spot period is also called the solar activity period, generally, the year that the sun has least black spots is the beginning of the cycle. Internationally it has been assumed that the year of the lowest value after 1749 (1755) as the beginning of the first cycle of the solar activity. Presently, it has completed 19 cycles and the 20th ~~has~~ WAS started in 1964. Based on the analysis of black spot numbers and the relationship between the solar activity and the amount of radio-active carbons in the air. The solar activity includes, besides the well-known eleven-year cycle, the magnetic cycle of 22-24 years, the century cycle of 80~100 years, the planets interacting cycle of 170~200 years, the cycle of 400 years even up to 2500 years, etc. The change of weather due to the solar activity is reflected on all these cycles.

The Temperature Change

Let us first examine the relationship between the temperature change and the solar activity. As early as the 17th century, it

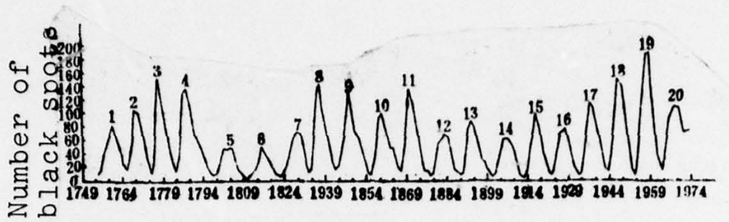

Figure 1. The number of black spots of the sun, 1749-1972 (digits on the curve are the order number of solar activity cycle).

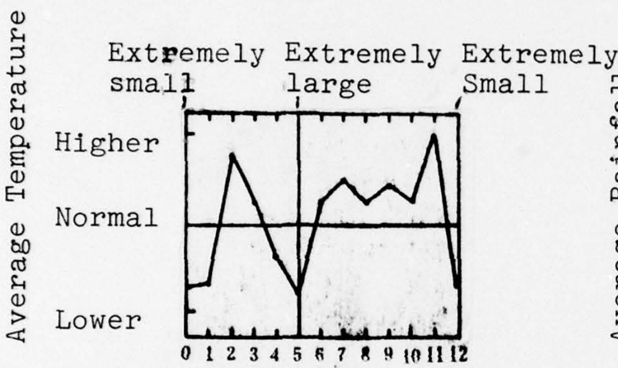

Figure 2. year of the black spot

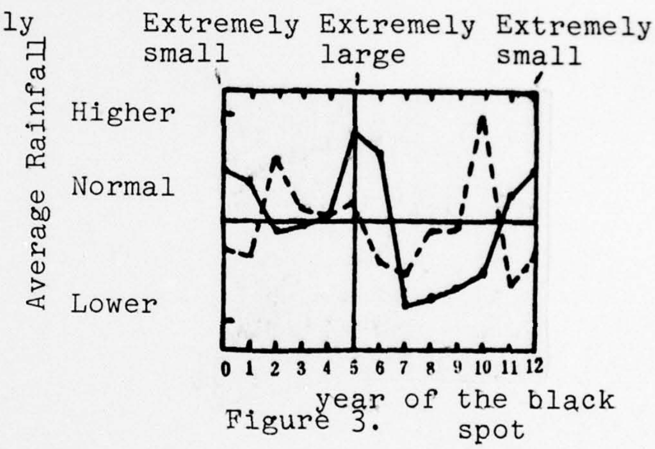

Figure 3.

Figure 2. The large range temperature change in China in the 11th cycle year of black spot.

Figure 3. The changes of rainfall in the 11th cycle year of black spot (the solid line shows northern China and the dotted line shows the downstream area of the Yantze River).

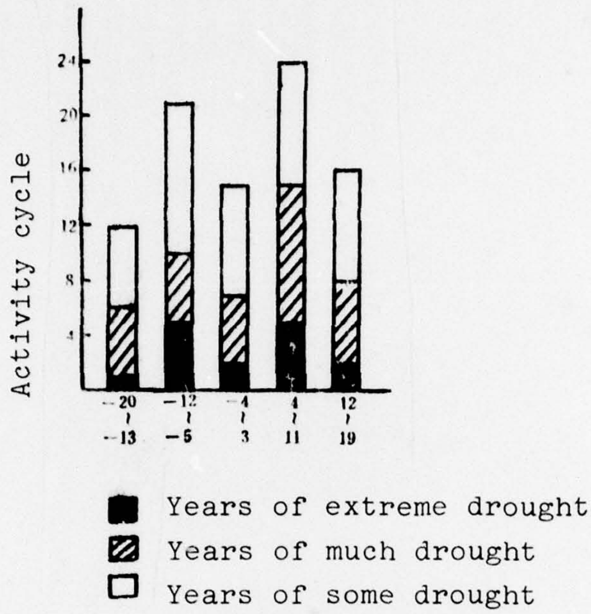

Figure 4. The frequency of drought year in the solar activity cycle in various centuries (before 1755 the activity cycle is indicated in negative digits).

has been pointed out that the temperature on earth decreased with the increase of solar black spots. Based on a large amount of temperature data, when the 11 year cycle moved from a low to a high value, the temperature in the tropic and polar regions decreased up to 0.5°C; only the mid-latitude region has the least temperature decrease ($<$ 0.1°C). Actually the temperature also depended on longitude. For example, when the solar activity is high the temperature decreased in Southeast Asia but increased in Northwest Europe and Central America. This has illustrated that the average temperature along a latitude in the 11 year cycle can be both high and low, as represented by the single wave phenomenum. However, the temperature change in our country with regard to black spot change in the 11 year cycle may be represented by a double wave phenomenum (Figure 2). According to studies, the double wave phenomenum which characterized by two maximum and two minimum temperatures in a cycle was not only common in China but also in Northern hemisphere. For example, the cold winters in Europe tended to concentrate in the years having black spots at extreme numbers. The summer temperature in North America behaved similarly. Actually the double wave phenomenum is related to the amount of solar radiation, as demonstrated in the change of the fixed radiation during the 11 years of solar activity. The single wave phenomenum may be related to the radiations of the sun, upper atmosphere and other stars.

In this century, the temperature range in our country may be divided into two warm periods (1919~1930, 1938~1949) and three cold periods (1909~1918, 1931~1937, and 1950 thereafter). It is interesting to observe that the change of periods happened to fall within 1~2 years the years of high solar activity, demonstrating a 22 year cycle. The years of high solar activity in the odd number cycle corresponded the year in which the cold period in China ended and the warm period began, while the opposite is also

true for the even number cycle. When the magnetic cycle of 22 years moved, it was also reflected in the weather of North Europe and North America. As we know, the 22 years cycle of the sun contained two 11 year cycles. When one of which is at the maximum value, the sun's two half surfaces have opposite magnetic polarity as the surrounding black spots. Consquently, the charge particles in the ~~elevated~~ (high) atmosphere for the two 11 year cycles were different, and the amount of energy radiated from the sun were also different for the odd and even number solar cycles.

Judging from the temperature variation record of our country, one may also observe its dependency on the solar activity. China probably has the most complete record on black spots and polar light activities. If we correlate the solar black spots and the number of polar lights in the record with the number of cold winters in our country, we can see that the century with highest number of black spots has always had most severe winters. This reflected the dependency of our historic weather on the solar activity over the 400 years or more.

THE RELATIONSHIP WITH THE AMOUNT OF RAINFALL

What was the relationship of the amount of rainfall and the solar activity in our country? The amount of rainfall depended on many factors but was mainly represented by a double wave graph of black spots in the 11 year cycles. However, the shape was different far north and south. For instance, the amount of rainfall in North Central China tended to be plentiful in the year the black spots were at an extreme value while scarce between those years. However the lower ~~Youngsze~~ Yangtze River region (central) was just the opposite (see picture 3). The change of rainfall in the upper and middle ~~Youngsze~~ Yangtze River regions, as indicated in the water level and flowing capacity at Han Ko city cor-

respond~~e~~s to black spots of 11 year cycles having complete wave graph entirely different from that of lower ~~Youngsze~~ Yangtze region. The black spots in the 11 year cycles in Northeast China and central region was, however, of single wave character. As we can see, the relationship between the solar ~~actibidy~~ activity and the amount of rainfall is quite complicated and still needs much more study.

The amount of summer rainfall in the middle and lower ~~Youngsze~~ Yangtze regions ~~and~~ was closely related to the timing of spring raining season. In the last century, and the third decade and ~~the~~ fifth decade of this century, the arrival of the spring rain was quite early and during these periods, most parts of our country have had substantial rainfall. On the other hand, the timing of the spring rainfall and the magnetic cycle of the solar activity also beared an obvious correlation. For example, the arriving time at the even years cycle of the solar activity at an extreme value was about ten days later than that of the odd year cycle. This was especially so for the year with maximum value as it came at least 15 days late. In addition, many other natural occurrings also happened to have about 11 year cycles. For example the cycle of the typhoon in the west Pacific was about 80-90 years, approximately the multiples of 11, opposite to the century change of solar activity.

The long-term change of drought years was an important indicator for weather change. In China during the last 500 years, it was not only relating to the 11 year cycle of the solar activity, but also to the 22 years, 80-100 years and 170-200 years cycles. When the solar activity has only weak interaction with the near-by satalites, the frequency for drought years increased. On the other hand, if the interactions was strong, the frequency decreased. ~~Consequent-~~ Consequent-ly the maximum frequency for drought years appeared every 80-90 years during the century cycle of solar activity. The last most frequent period was between the 8th decade of the 18th century and the 7th decade of 19th century. It

has been forcasted that a new high frequency drought period will begin in the 20th cycle. In the past, the draught years of significance have been around the 11 years cycle black spots at low values, especially in that of even cycle. The most significant drought years in the last 500 years of Chinese history such as the ones in 1721, 1785, 1877 were around the minimum value of the even cycle, except for the one of 1640. From above one can see how the solar activity has affected the weather in our country. What worths most attention was that the flood years, drought years and exceptionally cold years all fell on the years of solar black spots of extreme values. The above has illustrated the dependency of damaging weather on the solar activity.

In practice, the amount of radiation energy received by the earth depends not only on the forth-mentioned internal change of solar radiation energy, also on its relative position with the sun, the amount of water vapor, ozone, carbon dioxide, dust (mainly from vulcano ash) in the atmosphere, the change on the surface of the earth such as snow and ice and the activities of the mankind. The solar activity often manifests in the atmospheric current which bears a direct influence on the weather of various regions. Therefore, the way the solar activity is affecting the weather is a very complicated process and many aspects still need further study.

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